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AUTOMATING A FLUID MILK PROCESSING LINE-- EQUIPMENT AND PROCEDURES

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CONTENTS

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AUTOMATING A FLUID MILK PROCESSING LINE--EQUIPMENT AND PROCEDURES

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SUMMARY

Engineers of the Transportation and Facilities Research Division, Columbia, Mo., in cooperation with the Department of Food Science and Nutrition, Missouri Agricultural Experiment Station, have designed and installed an automated system for the fluid milk processing line in the University dairy plant. The automated system was designed to minimize the equipment used, permit complete cleaned-in-place (CIP) cleaning, reduce labor requirements for processing and cleaning, and meet Federal, State, and local regulations regarding installation and operation.

This publication contains a detailed explanation of the various operating and controlling units. Wiring diagrams are also provided to assist dairy plant engineers in evaluating the system.

The total cost in 1967 was \$15,560.50–\$12,560.50 for the equipment and \$3,000 for its installation. The total fixed cost is \$45.99 per week. The chart presented at the end of this publication permits a plant manager, using the wage scale in his plant, to determine how much labor the system must eliminate to be advantageous for him.

INTRODUCTION

Competition is causing the dairy industry to look to automation to lower operating costs. In automation, a phase in the evolution of mechanization, mechanical operations are brought under automatic controls. Its objective is to reduce the manpower needed to perform dairy operations, without sacrificing the healthfulness or quality of the product.

This study concerns the equipment and procedures for automating a fluid milk processing line. An efficient fluid milk processing line must minimize the equipment used, permit complete CIP cleaning, and meet Federal, State, and local regulations regarding installation and operation.

A new CIP flow-diversion valve, and a procedure for installing the valve that uses the homogenizer as a timing pump, made it possible to design a fluid milk processing line that meets these objectives. The flow diversion valve has been approved by the United States Public Health Service, and use of the homogenizer as a timing pump is discussed in a publication by Anderson and others.[2]

The system we have designed has been installed in the dairy plant at the University of Missouri at Columbia and operates on a regular processing schedule. It has been in service for more than a year without a malfunction of any consequence. This publication describes the various components of this system, and the way they operate.

DESCRIPTION OF THE SYSTEM

An automated fluid milk processing system processes milk and milk products. For this publication, the system includes the raw and pasteurized milk storage tanks and accessories as well as the processing equipment. The two basic units in the system are for controlling and operating. A controlling unit energizes and deenergizes

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[2] Anderson, M. E., Webb, T. F., Marshall, R. T., and Shelley, D. S. Adapting the flow-diversion valve and homogenizer to permit automated cleaning-in-place of milk processing lines, U.S. Dept. Agr., Agr. Res. Serv. 52-31, 18 pp., illus., January 1969.

an operating unit and consists of one or more electrical components, for example, an electrical switch. An operating unit is any item of equipment (with its related components) that performs a specific function in the processing system. For example, the homogenizer, including its motor starter, is an operating unit that homogenizes the milk; and an air-actuated valve, including its solenoid-operated air valve, is an operating unit that directs the flow of milk. An automated milk processing system consists of various operating units and their respective controlling units.

Controlling Units

The following are typical components of a controlling unit: a three-position switch (called a position switch), an indicator light, a selector switch, and a relay.

A position switch (hand–off–automatic) controls one or more operating units. The "hand" setting is used for manual control, and the "automatic" setting transfers control of the operating unit to another controlling unit, for example, a relay (fig. 1).

An indicator light shows when an operating unit is energized. Figure 2 shows a position switch and an indicator light mounted on the control panel.

A selector switch (often referred to as a rotary switch) chooses different operations to be performed by the operating units. Figure 3 is a schematic of a selector switch with an indicator light. When the selector switch is in the No. 1 setting, moving the position switch to the "hand" setting energizes operating units 1, 2, and 3. If the selector switch had been set on 2 or 3, operating units 1, 4, and 5, or 1, 6, and 7, respectively, would have been energized. By setting the position switch on "automatic," the respective units are energized when the relay is energized. Figure 4 shows two selector switches that may be used in a control panel.

Relays are used in control circuits to energize operating units and other controlling units and to prevent feedback. Energizing the relay coil forces a plunger, which controls the contact points, to change positions (fig. 5), causing the normally open (N.O.) contact points to close and the normally closed (N.C.) contact points to open. Industrial and plug-in-relays (fig. 6) are the most common types used in a controlling unit.

A controlling unit may include nonelectrical components. The liquid level controlling unit, which contains both air- and electrically-operated components, is an example. This unit permits removal of a predetermined weight of milk from the tank. Also, the quantity of milk in the tank may be read from a manometer (fig. 7). The controlling unit consists of a sensing device, two manometers, and a controller (fig. 8). The controller is located in the control panel shown in figure 7. The sensing device, located on the side of the tank at the bottom, contains two basic parts—an orifice and a diaphragm. A small volume of low-pressure air flows through the orifice against the diaphragm. The pressure of the milk in the tank forces the diaphragm against the orifice, restricting the orifice outlet. This restriction results in increased pressure in the air line. The air pressure in the line is registered on a read-out manometer, calibrated in pounds of milk.

A batching manometer is located next to the read-out manometer. The batching manometer controls several operating units that remove a predetermined amount of milk from the tank. For this operation, the batching manometer is adjusted to read the weight of milk that should remain in the tank. The transfer-from selector switch (described later) is moved to a setting that selects the tank from which the milk is to be removed. Both the position switch and the tank-empty switch on the liquid level control panel are set on "automatic." When the required weight of milk is removed from the tank, the circuit is deenergized because the pressure in the two manometers has been equalized.

Operating Units

Operating units are identified by their function, for example, a valve unit directs the flow of milk. A sanitary valve unit (called a valve unit) consists of an air-actuated sanitary valve and an electrically-operated solenoid air valve (fig. 9). The sanitary valve consists of three basic parts—an air actuator, a valve body, and a valve stem (fig. 10). Pressurized air enters the actuator, causing the valve stem to change position. Release of air pressure allows the valve to move to its original position due to spring tension. A sanitary valve is set in either of two positions, normally open or normally closed (fig. 11). When pressurized air flows into the actuator on a normally open valve, the valve stem moves to the closed position; whereas, if the valve were normally closed, the valve stem would move to the open position.

The three types of air-actuated valves commonly used in a milk processing system are the shutoff valve, Y-valve, and divert valve (fig. 12). Function determines the choice of the valve.

In addition to sanitary valves, the milk processing system (fig. 13) contains the following operating units:

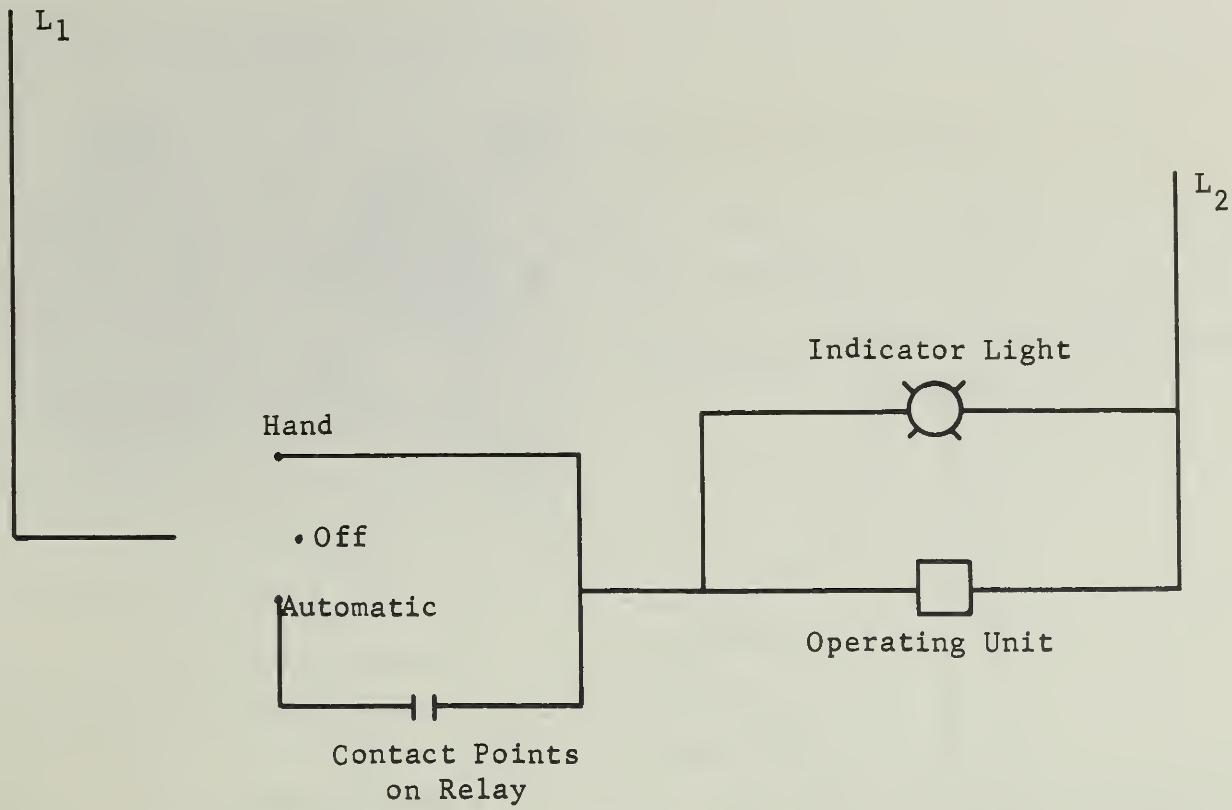


Figure 1.–Schematic of three-position switch with indicator light, relay, and an operating unit.

Figure 2.–A three-position switch and an indicator light.

(the numbers in figure 13 indicate operating units and their positions in the processing system): positive pump (1), separator-clarifier (2), agitator batching tank (3), centrifugal booster pump (4), CIP booster pump (5), vacuum pump (6), two-speed centrifugal pump (7), homogenizer (8), pasteurizer heater (9), flow-diversion valve assembly (10), sweetwater pump (11), agitator milk tank No. 1 (12), agitator milk tank No. 2 (13), agitator milk tank No. 3 (14), and agitator milk tank No. 4 (15). Each unit is controlled by a position switch or a selector switch. Although the CIP booster pump does not operate during processing, it is included because of the importance of its location in the line. The two-speed centrifugal pump has two functions: on low speed it is used as the homogenizer feed pump (fig. 13, 7-A) and on high speed as a CIP pump (fig. 13, 7-B). We will refer to these as the homogenizer feed pump and the CIP pump.

The function of each operating unit depends on the cycle of operation. For example, during processing the homogenizer is operated to reduce the size of the fat globules; but during the cleaning cycle the homogenizer is operated only intermittently so that it may be cleaned in place.

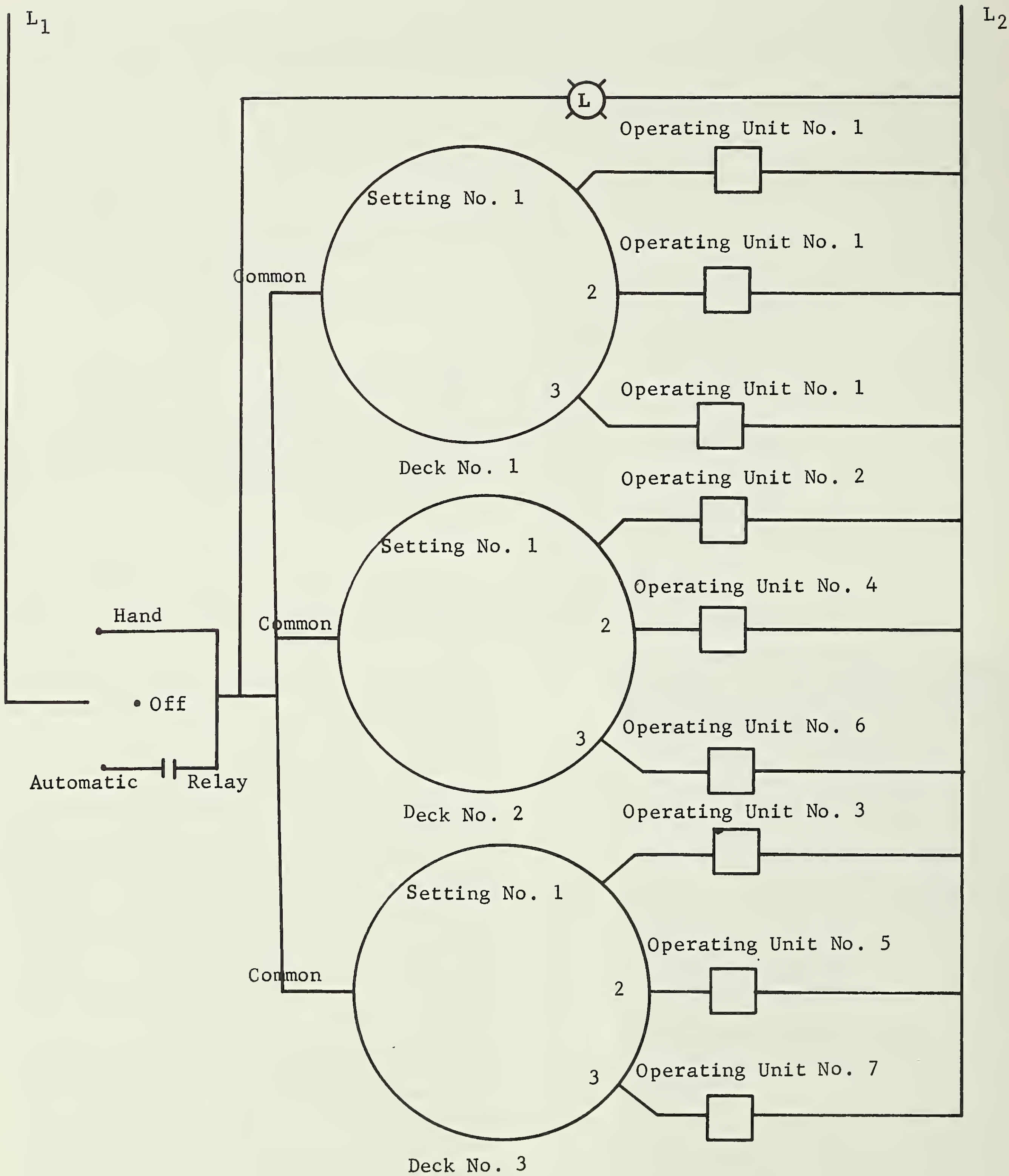


Figure 3.–Schematic of a selector switch controlled by a three-position switch.

Figure 4.–Two common types of selector switches used in control panels.

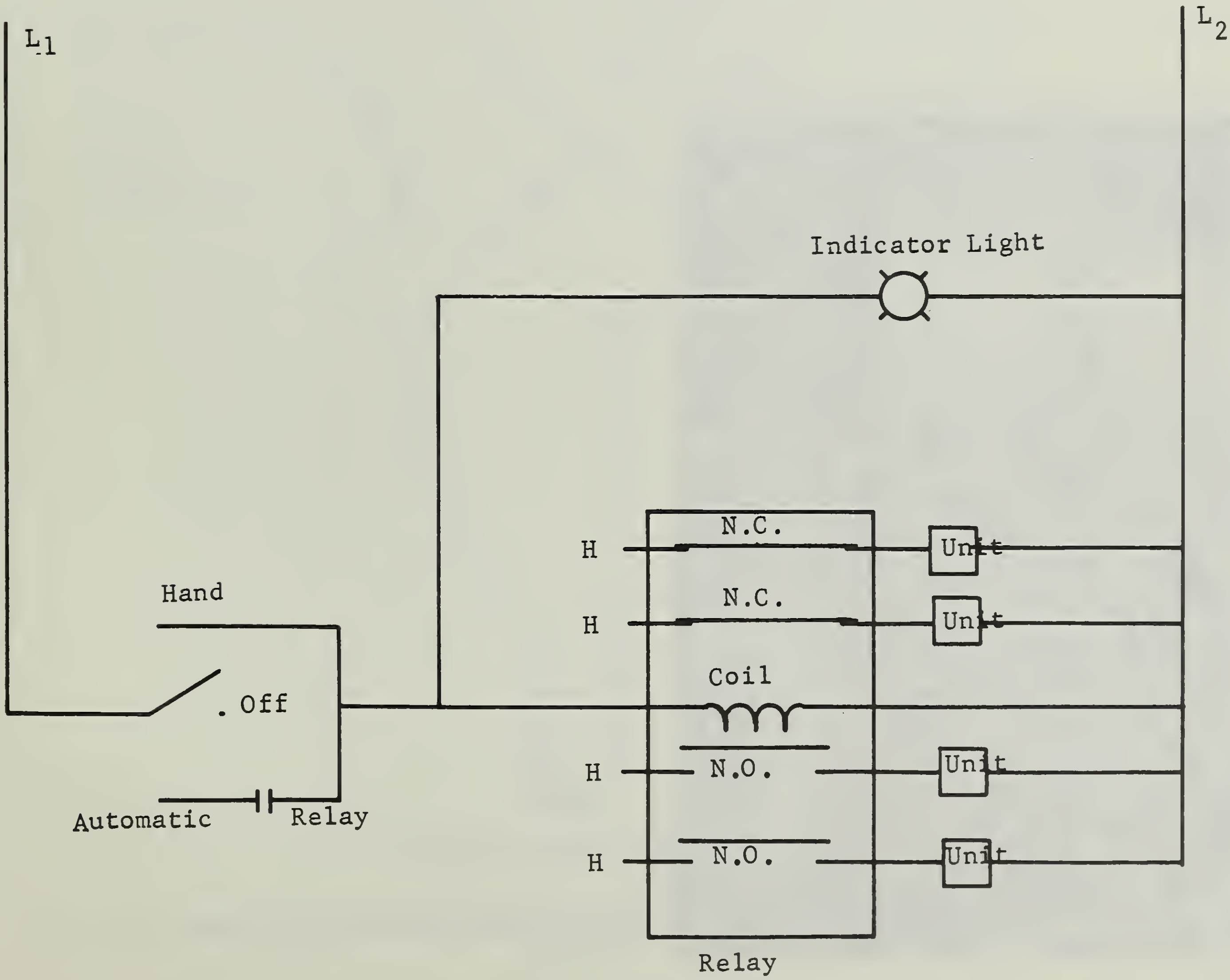


Figure 5.–Schematic of a relay controlled by a three-position switch.

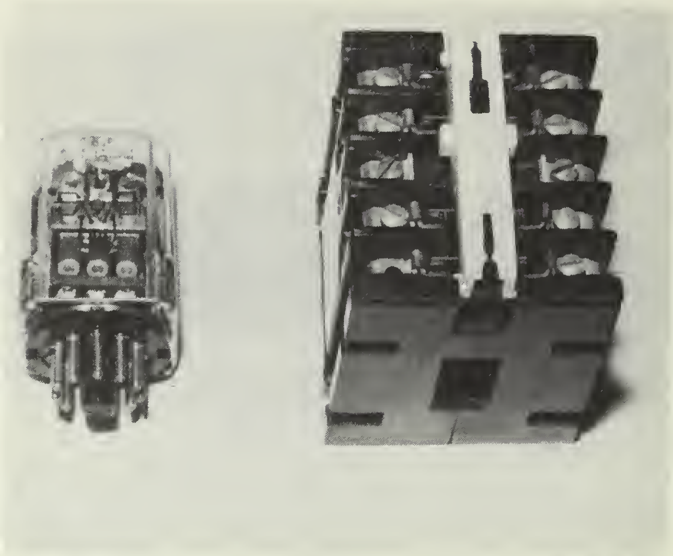


Figure 6.–An industrial and a plug-in type relay.

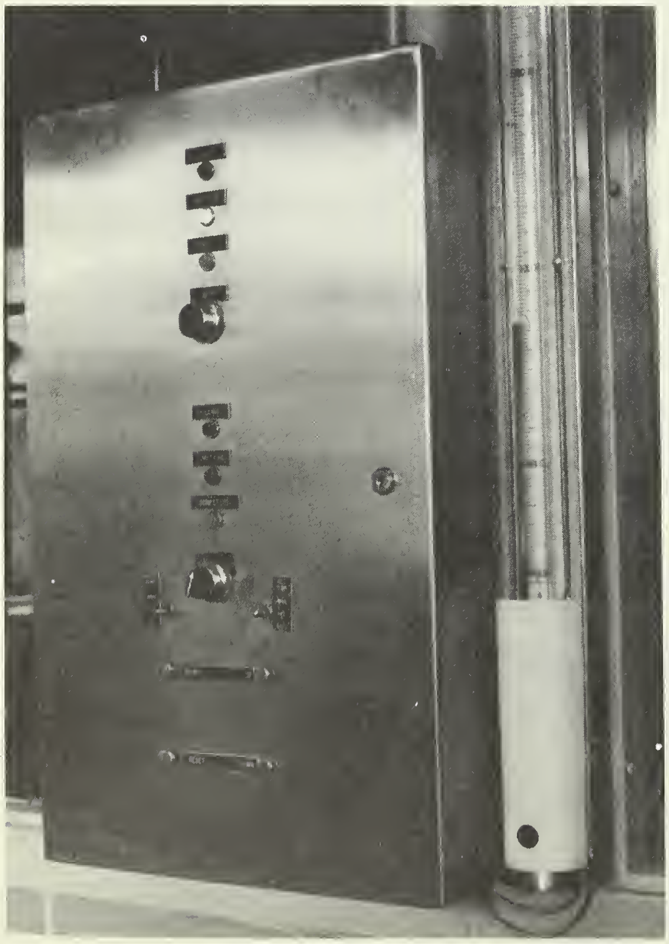


Figure 7.–Control panel and manometer gage for liquid level control unit.

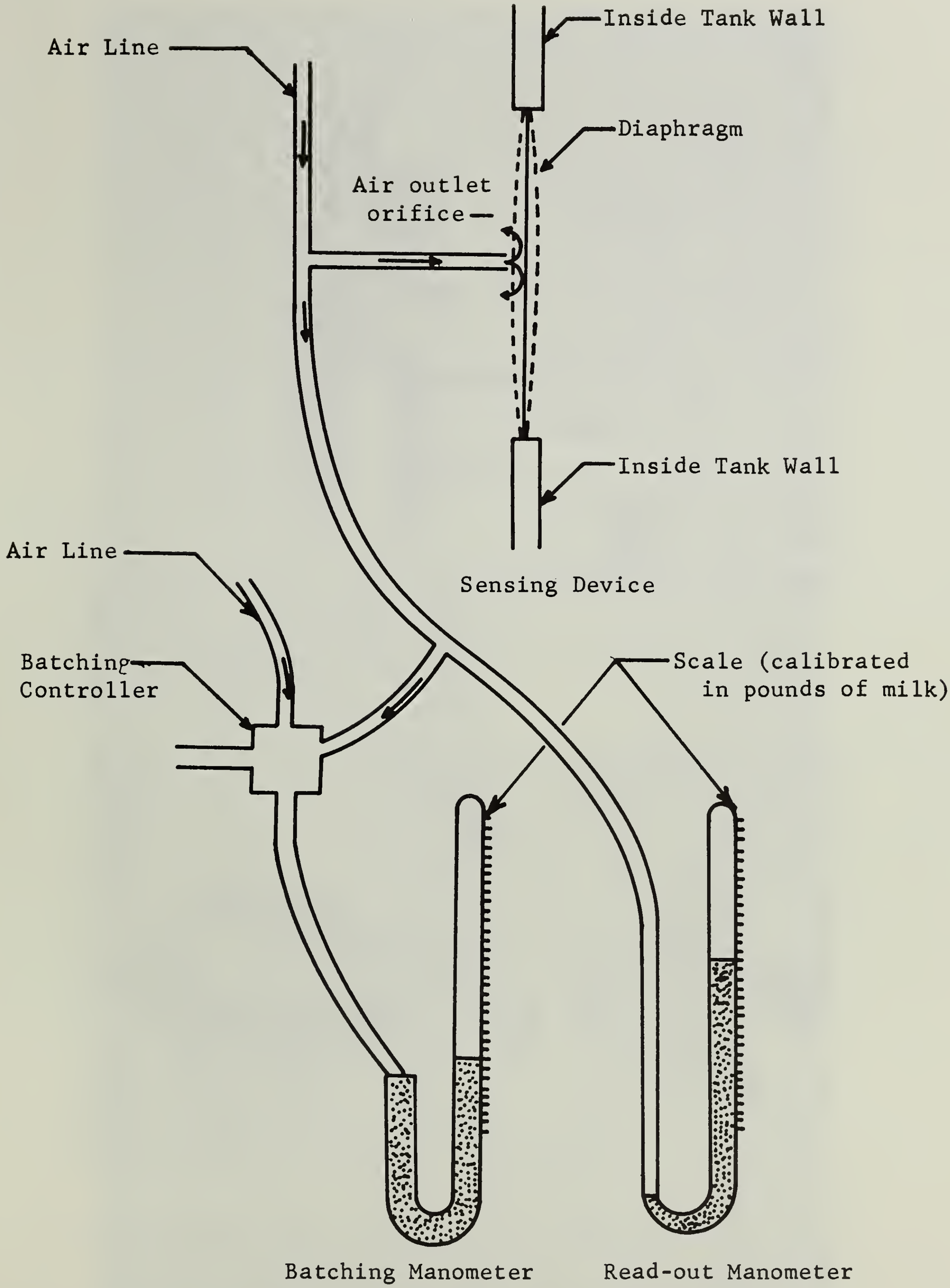


Figure 8.–Schematic of liquid level unit.

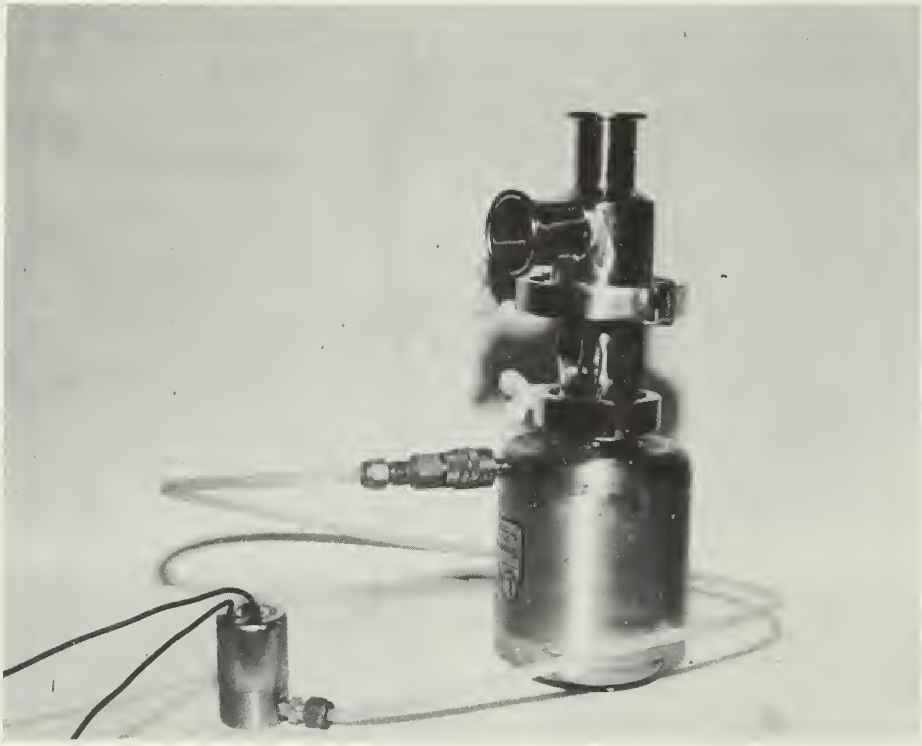


Figure 9.–Components of a sanitary valve unit–solenoid and air-actuated valve.

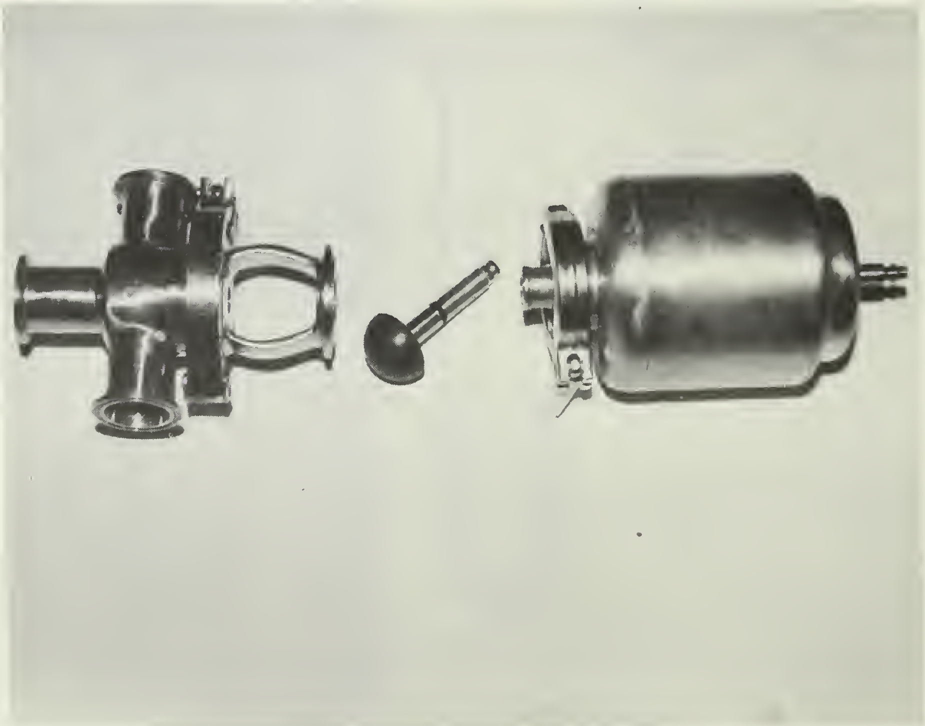


Figure 10.–The basic parts of a sanitary valve–valve body, valve stem, and air-actuator.

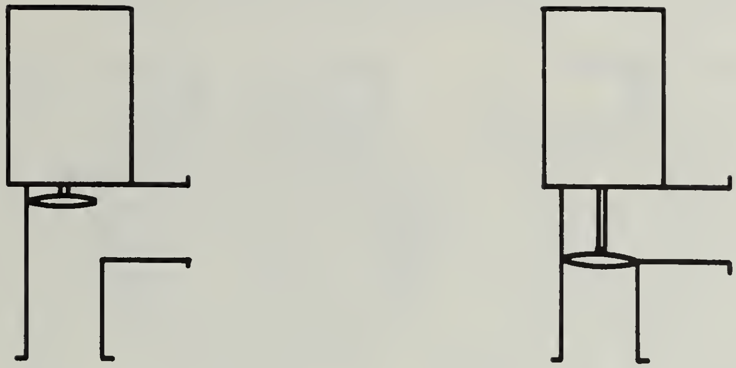


Figure 11.–An air actuated shutoff valve with the valve stem in two different positions–normally open and normally closed.

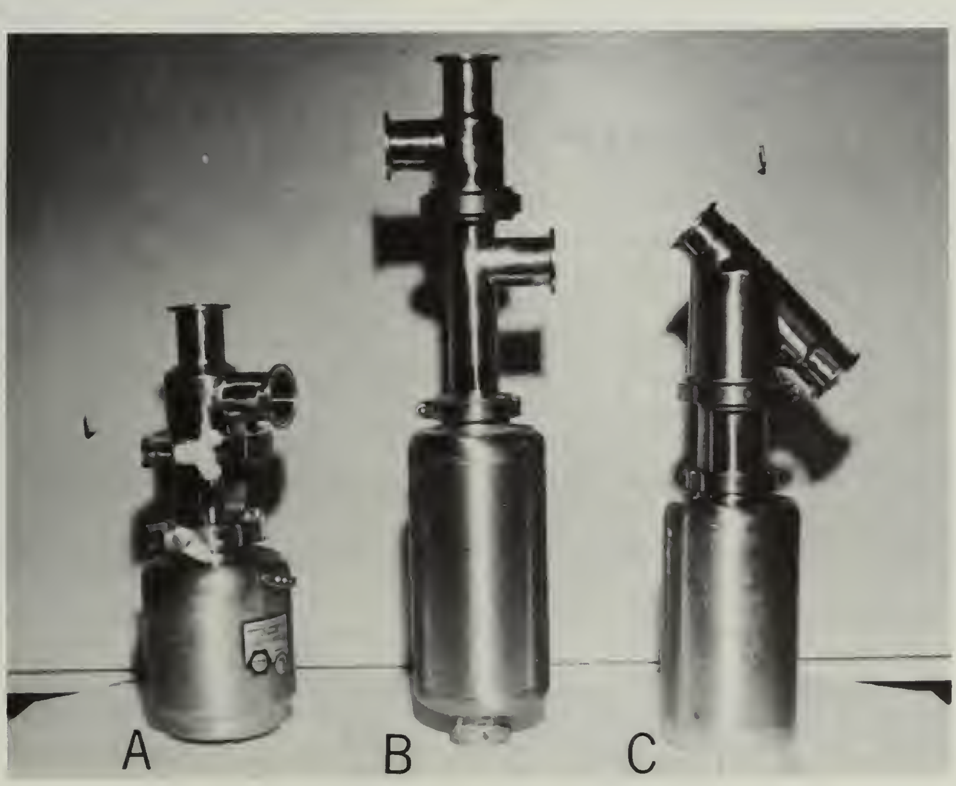


Figure 12.–Three types of sanitary valves commonly used in milk processing lines: *A*, shutoff valve, *B*, divert valve, *C*, and Y-valve.

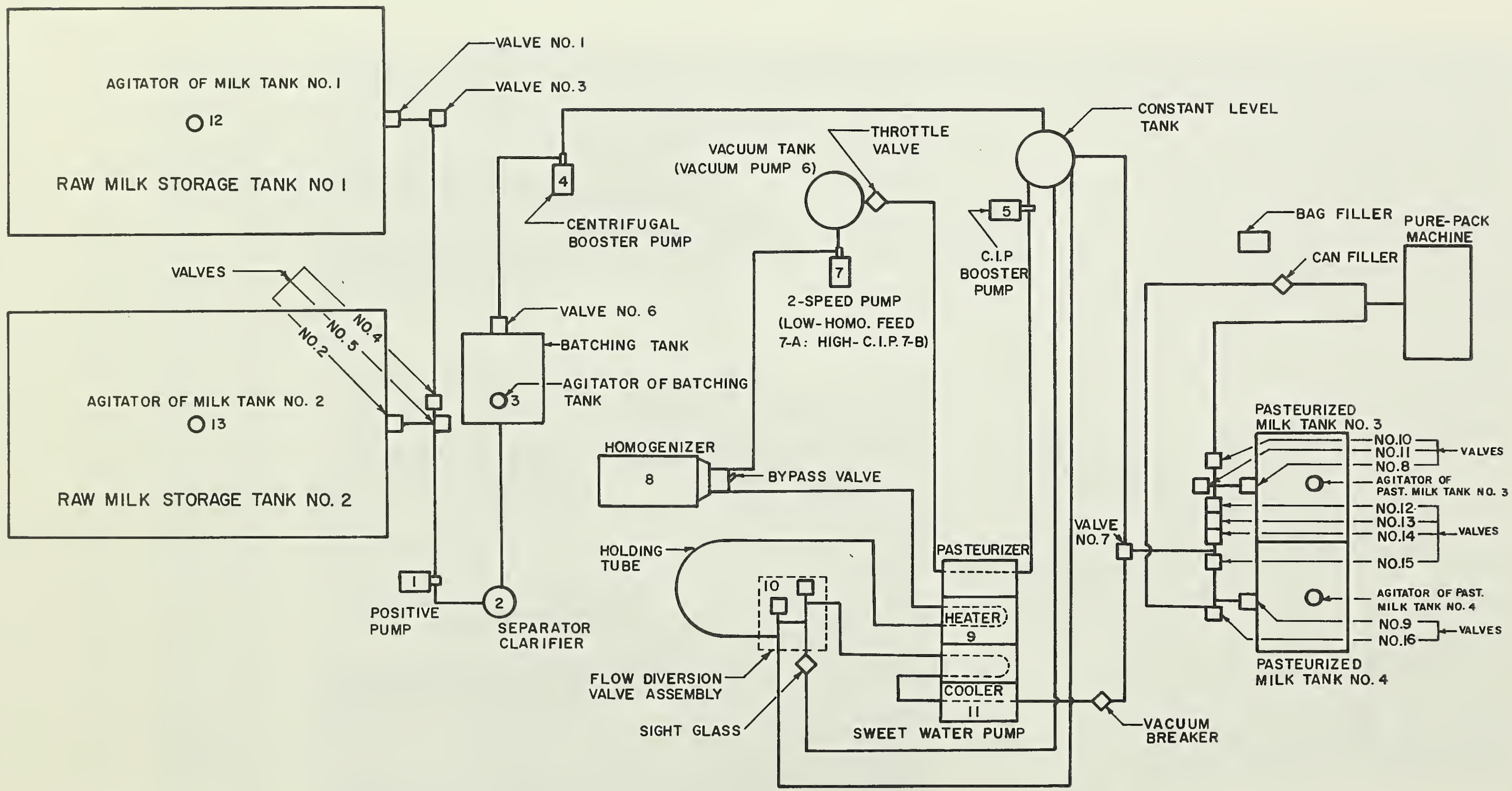


Figure 13.—Schematic of the flow of milk through the processing system.

The processing operations described in this publication consist of standardizing, separating, batching, and processing (packaging is not included). Milk is moved from the storage tank through the separator-clarifier, the batching tank, the processing line, the pasteurized milk storage tank, and to the Pure-Pak machine, the bag filler, or the can filler. These operations are controlled by three selector switches (fig. 14)—transfer-from, process, and transfer-to—and seven position switches (fig. 15). Wiring diagrams show the necessary circuitry.

When the selector switches are in any of the settings listed below, the circuit is energized by placing its position switch on "hand." The indicator light shows when the circuit has been energized.

TRANSFER-TO
SELECTOR SWITCH

TRANSFER-FROM
SELECTOR SWITCH

PROCESS
SELECTOR SWITCH

Figure 14.—Three selector switches control the transferring and processing of milk.

Transfer-From Selector Switch

The transfer-from selector switch directs the flow of milk from either of the two raw milk storage tanks. This raw milk may be pumped from the storage tanks back into a tank truck, or directed to the separator-clarifier for standardizing and processing.

Setting No. 1, used to remove milk from tank No. 1, opens valves 1 and 4; closes valve 5; and starts the agitator in raw milk tank No. 1.

Setting No. 2, used to move milk from tank No. 2, opens valve 2 and starts the agitator in tank No. 2.

Setting No. 3 is used to remove milk from tank No. 1 and direct it through the separator-clarifier to the batching tank. It opens valves 1 and 4; closes valve 5; starts the agitators in tank No. 1 and in the batching tank; and starts the positive pump and the separator-clarifier.

Setting No. 4 moves milk from tank No. 2, through the separator-clarifier, to the batching tank. It opens valve No. 2; starts the agitators in tank No. 2 and in the batching tank; and starts the positive pump and the separator-clarifier.

In setting No. 1 of the transfer-from selector switch (fig. 16), the energizing of relay "A" closes CP-1 (contact point No. 1) through CP-4, energizing valves 1 and 4, the agitator in tank No. 1, and valve 5, respectively.

In setting No. 2 (fig. 17), relay "B" controls valve unit No. 2 and the agitator unit in tank No. 2 from CP-1 and CP-2, respectively.

Figure 18 shows setting No. 3 of the transfer-from selector switch. Relays "A" and "C" are energized. (Relay "A" is described under setting No. 1.) CP-1 through CP-3 on relay "C" control the positive pump (used to move the milk from the storage tanks to the batching tank), the separator-clarifier, and the agitator in the batching tank.

Figure 19 shows setting No. 4 of the transfer-from selector switch. This setting energizes relays "B" and "C". (These relays are described under settings 2 and 3.)

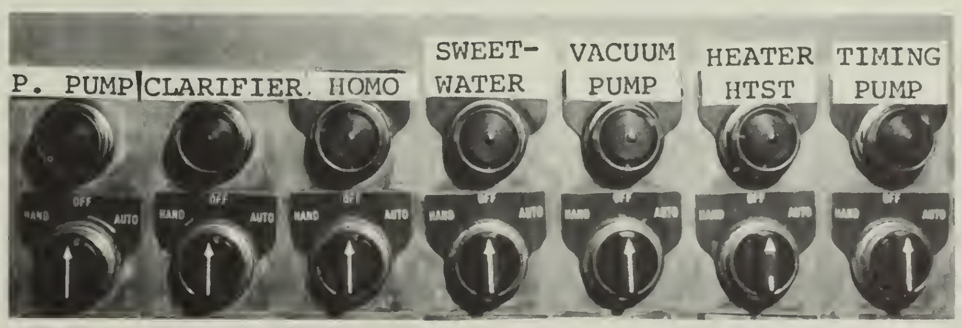
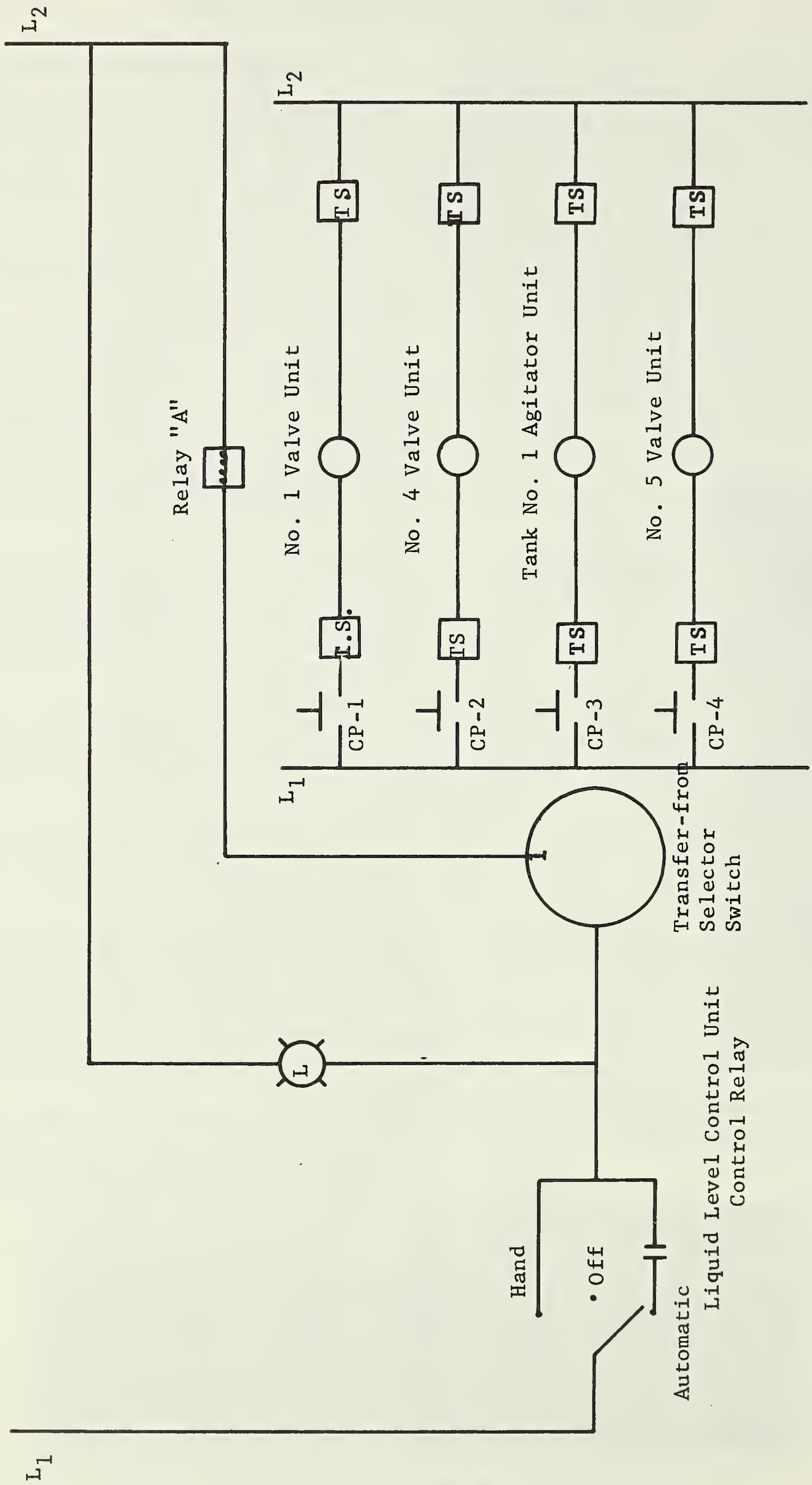


Figure 15.—Seven position switches control the equipment in the processing line.



L_2
L_1
Relay "A"
L_2
L_1
TS
T.S.
No. 1 Valve Unit
No. 4 Valve Unit
Tank No. 1 Agitator Unit
No. 5 Valve Unit
CP-1
CP-2
CP-3
CP-4
Transfer-from
Selector
Switch
L
Liquid Level Control Unit
Control Relay
Hand
Off
Automatic

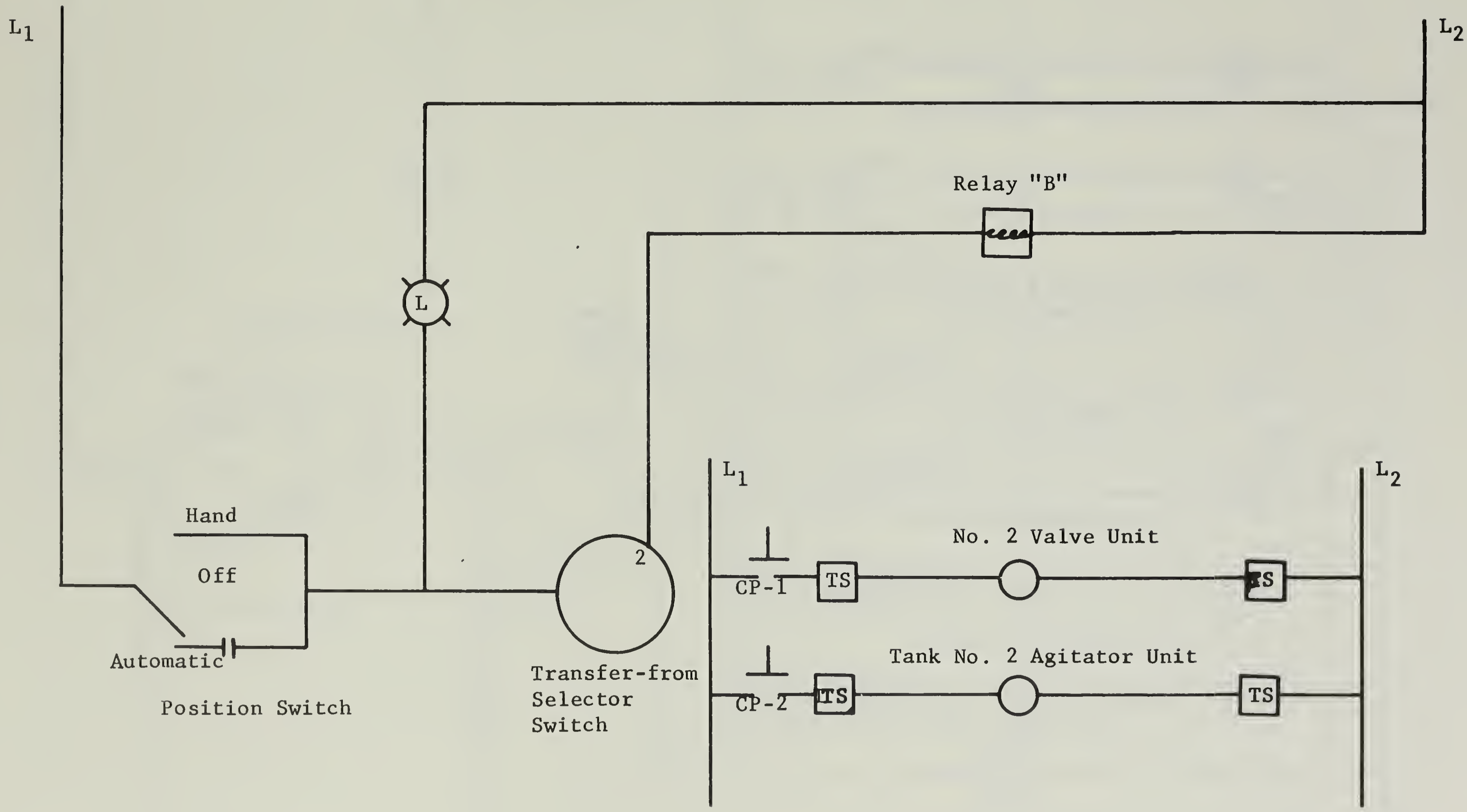


Figure 17.–Transfer-from selector switch–setting No. 2.

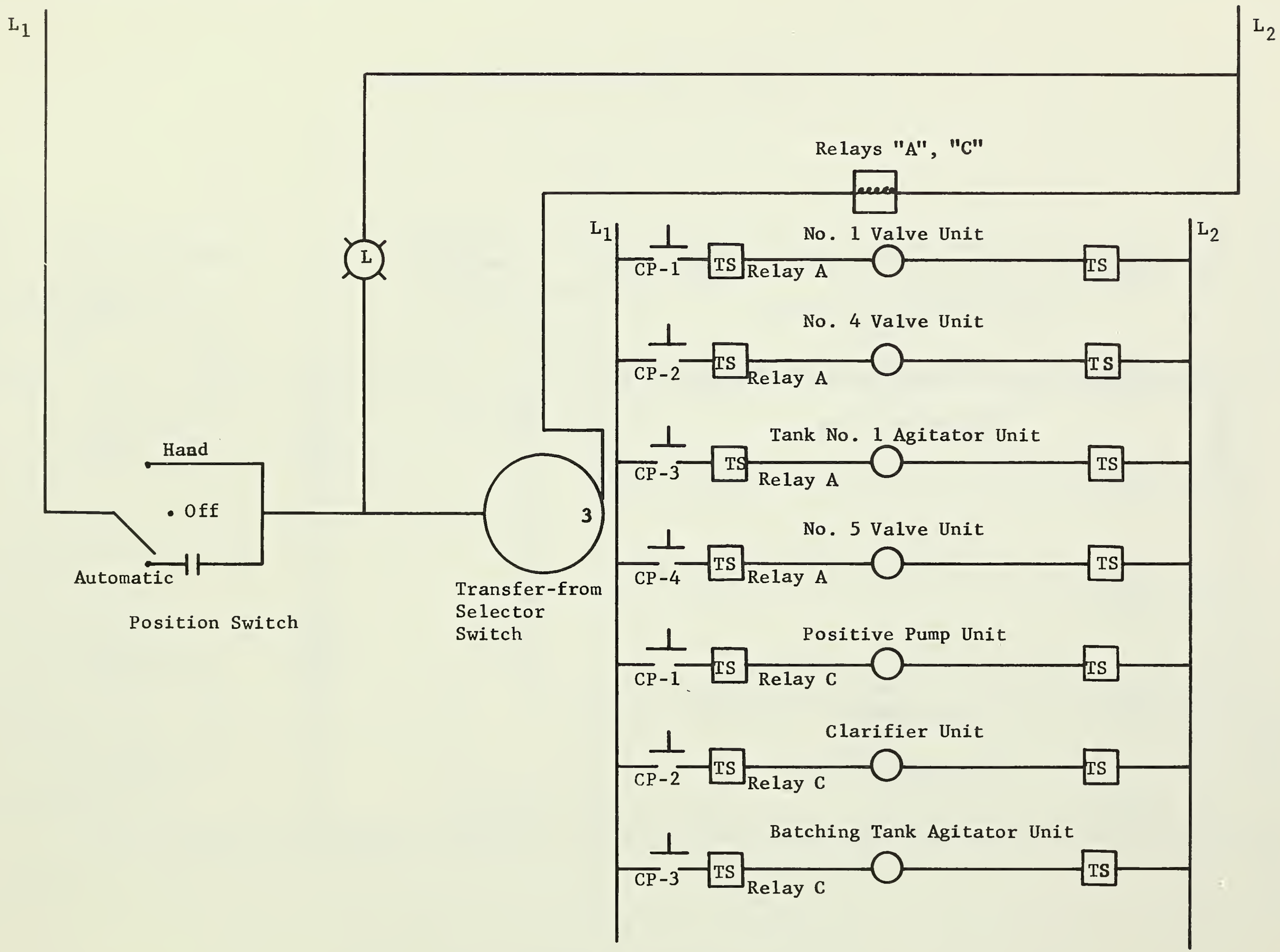


Figure 18.—Transfer-from selector switch—setting No. 3.

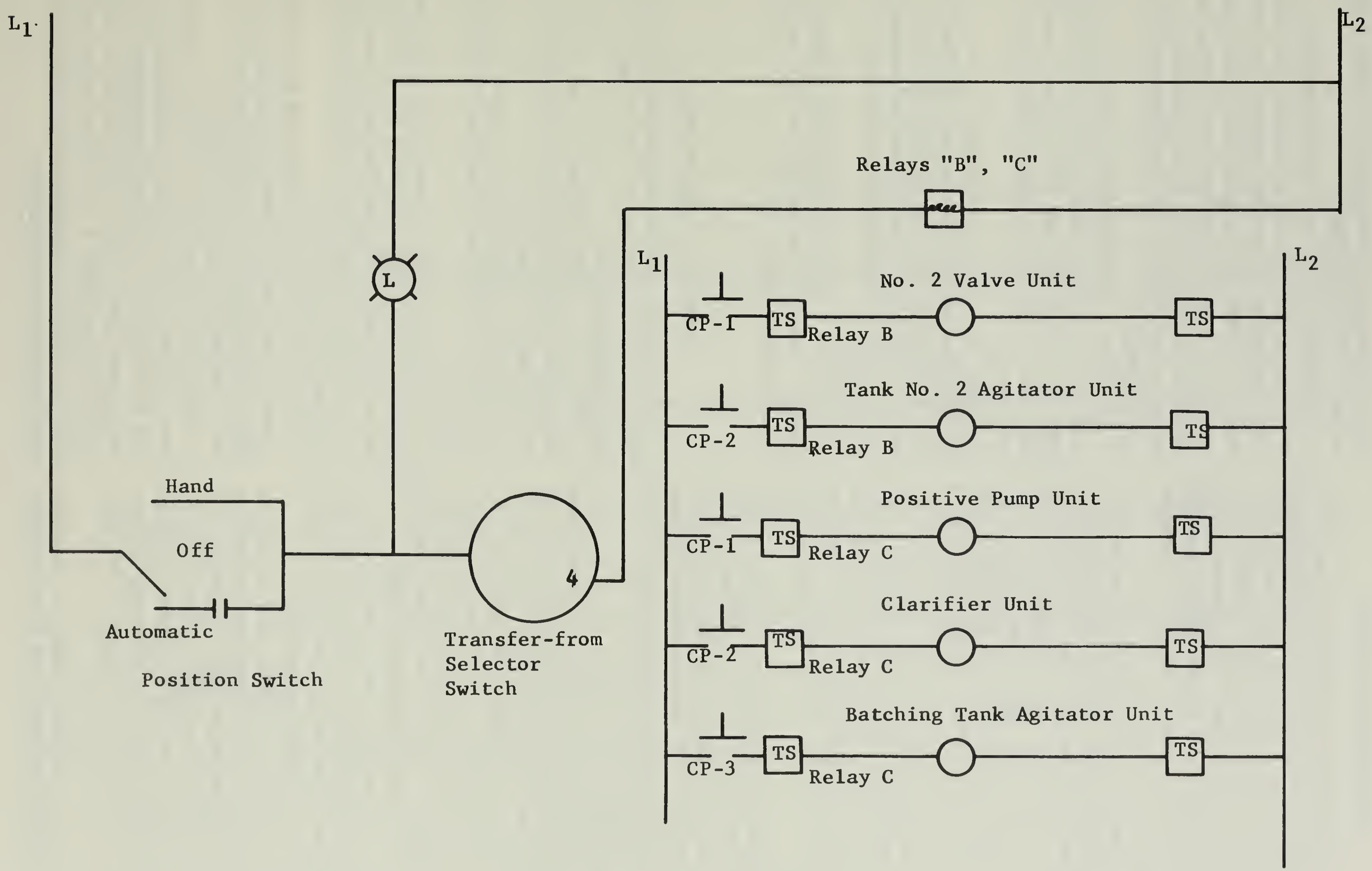


Figure 19.–Transfer-from selector switch–setting No. 4.

Process Selector Switch

The processing equipment units (fig. 13)—pasteurizer heater (9), sweetwater pump (11), vacuum pump (6), and homogenizer feed pump (7-A)—are controlled by the process selector switch when their respective position switches are on "automatic." The homogenizer (8) is controlled directly by a position switch because it operates under high pressure and should not be stopped under pressure.

During processing, the raw milk from the batching tank is circulated to the constant level tank by a centrifugal pump (4). The milk flows through the CIP booster pump (5) (which is not in operation), through the raw milk side of the regenerative section of the pasteurizer, and into the vacuum tank through the spray tube. The CIP booster pump (5) can be started by a manual switch from the control panel, or by a micro-switch on a processing line wash cycle cam timer, only when the flow-diversion valve selector switch is in the "clean" setting. The flow of milk into the vacuum tank is controlled by an air-actuated throttle valve, regulated by a liquid level controller located on the side of the vacuum tank.

The homogenizer feed pump (7-A) removes the milk from the vacuum tank and feeds it to the homogenizer (8). The bypass valve remains closed during the processing cycle. The milk from the homogenizer (8) flows through the heating section of the pasteurizer (9) and through the holding tube to the divert valve of the flow-diversion valve assembly (10).

With the flow-diversion valve in the forward-flow position (above pasteurization temperature), the milk flows through the flow-diversion valve (10), to the regenerative and cooling sections of the pasteurizer, to a flow-control valve (valve No. 7). The flow-control valve directs the flow of milk to the milk storage tanks and packaging equipment, or back to the constant level tank if milk is to be recirculated through the system.

Setting No. 1 of the process selector switch, which is used to start the processing cycle, moves the milk from the batching tank to the constant level tank by opening valve 6 and starting the centrifugal pump (4).

Setting No. 2, used to recirculate milk through the system, controls units in the processing line with the exception of the homogenizer. The flow-control valve diverts milk back to the constant level tank when the selector switch is in this setting. Setting No. 2 energizes the sweetwater pump (11), the pasteurizer (9), the vacuum pump (6), and the homogenizer feed pump (7-A).

In setting No. 3 (process setting), all the units previously mentioned (settings 1 and 2) are energized, and the flow-control valve is opened to permit the milk to flow to the storage tanks.

The process selector switch controls the units in the processing line with the exception of the homogenizer. (The homogenizer is controlled directly by its position switch, to prevent the electrical circuit from breaking accidentally when the homogenizer is operating under load.) The position switches for the various units must be set on "automatic" to be controlled by the process selector switch.

Setting No. 1 (fig. 20) is used to move milk from the batching tank to the constant level tank. Energizing relay "M" causes CP-1 and CP-2 to close, energizing valve No. 6 and the centrifugal booster pump (4), respectively.

Setting No. 2 (fig. 21) energizes all units in the processing line except the homogenizer (8). When relay "N" is energized, CP-1 through CP-4 are closed. This causes the pasteurizer heater (9), sweetwater pump (11), vacuum pump (6), and homogenizer feed pump (7-A) to be energized.

Setting No. 3 (fig. 22) combines the operations of settings 1 and 2. (The circuitry for this setting is explained under settings 1 and 2.)

Transfer-To Selector Switch

The transfer-to selector switch directs the flow of milk from the processing system to the storage tanks and the packaging equipment.

Setting No. 1 transfers the milk to tank No. 3. This setting opens valves 8, 12, and 14; closes valve 13; and starts the agitator in tank No. 3.

Setting No. 2 transfers the milk to tank No. 4. This setting opens valves 9 and 15 and starts the agitator in tank No. 4.

Setting No. 3 directs the flow of milk to tank No. 3, when it is used as a surge tank for the Pure-Pak machine, the can filler, and the bag filler. This setting opens valves 8, 10, 12, and 14; closes valve 13; and starts the agitator in pasteurized milk tank No. 3.

Setting No. 4 directs the milk to tank No. 4, when it is used as a surge tank for the Pure-Pak machine, the can filler, and the bag filler. This setting opens valves 9, 15, and 16, and starts the agitator in tank No. 4.

Setting No. 5 directs the flow of milk to tank No. 4, when it is used as a holding tank, and directs the flow of milk from tank No. 3 to the packaging equipment. This setting opens valves 9 and 15, allowing milk to flow to tank No. 4; opens valves 8 and 10, allowing the milk to flow from tank No. 3 to the packaging equipment; and starts the agitators in tanks 3 and 4.

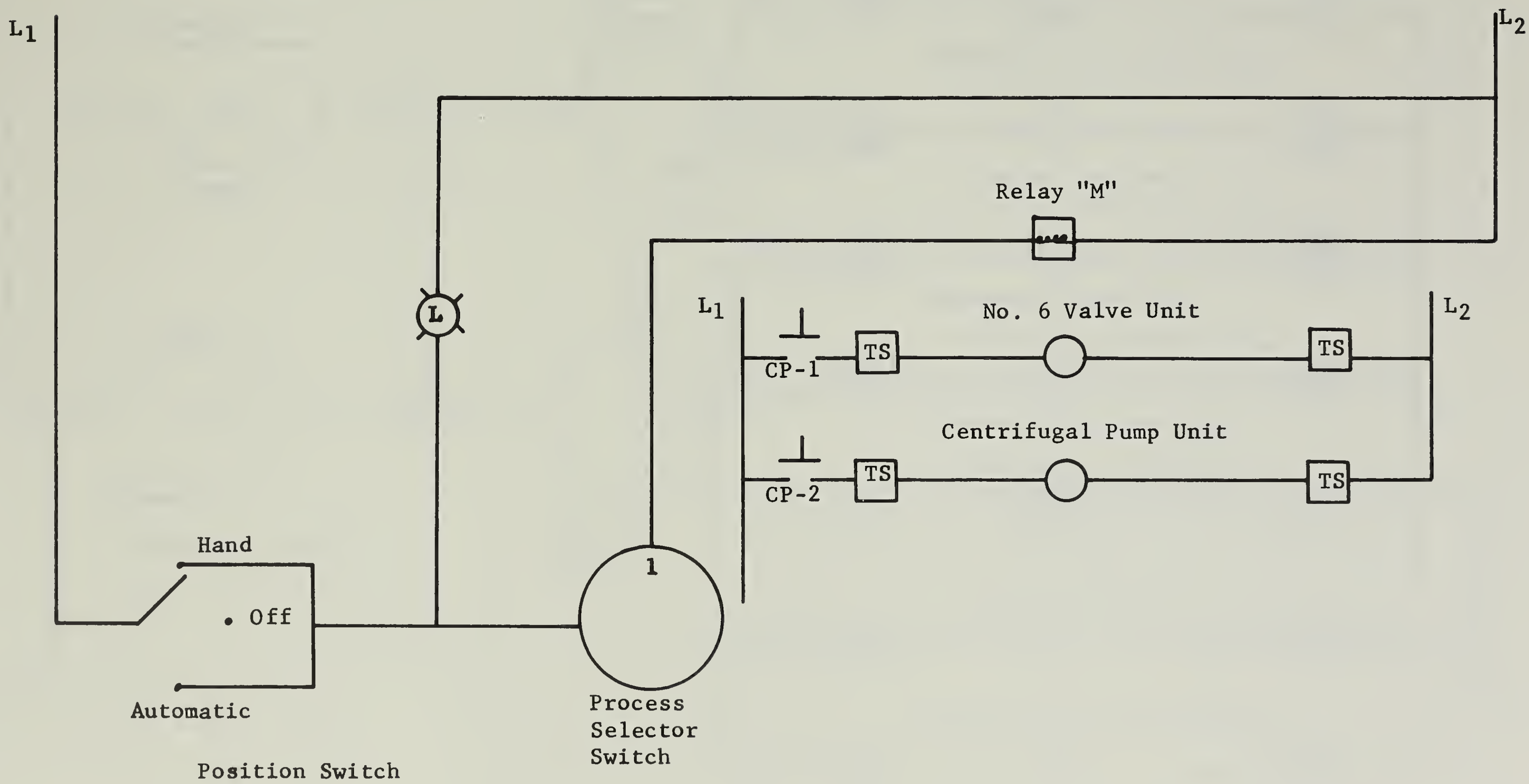


Figure 20.–Process selector switch–setting No. 1.

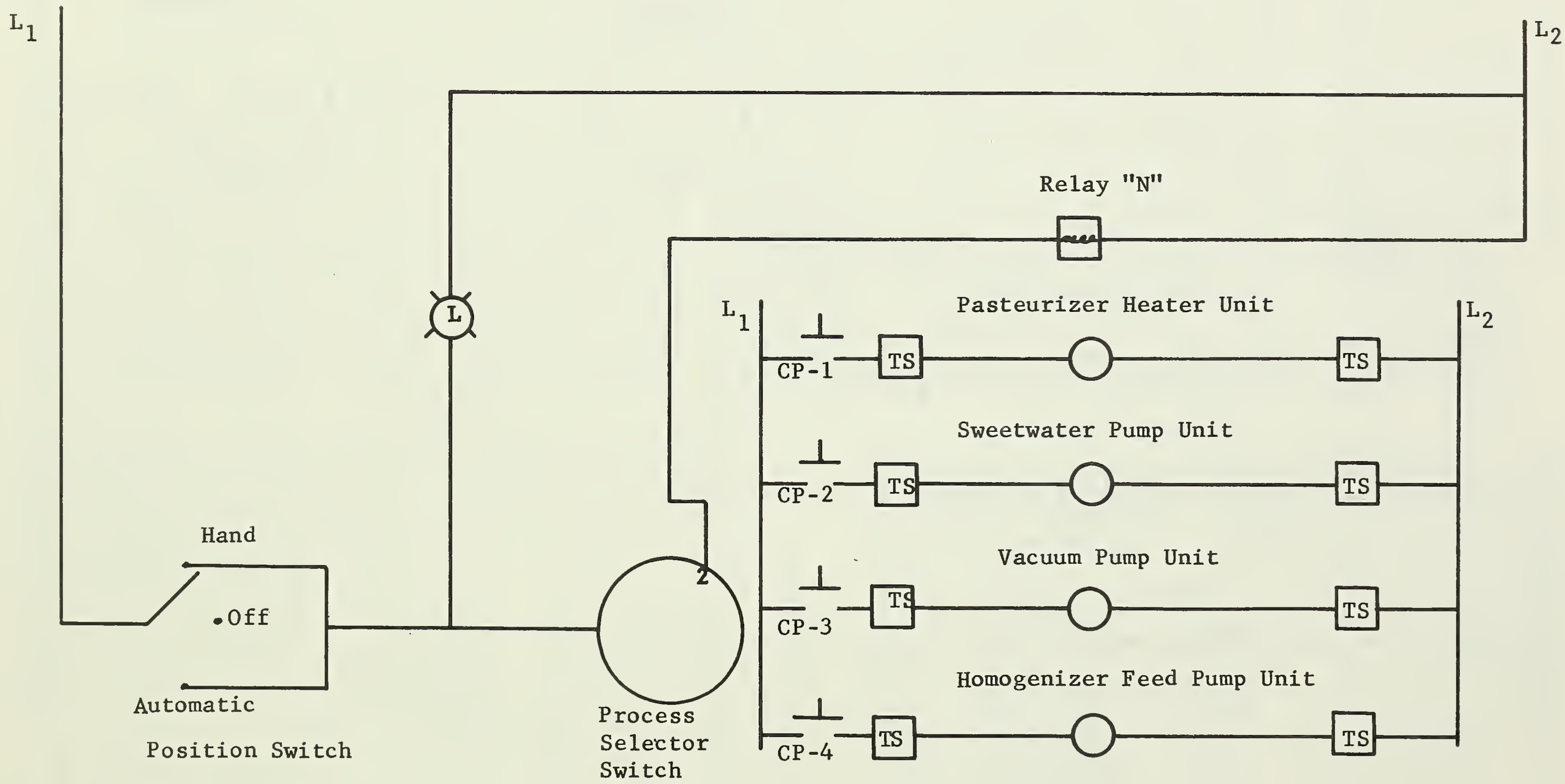


Figure 21.–Process selector switch–setting No. 2.

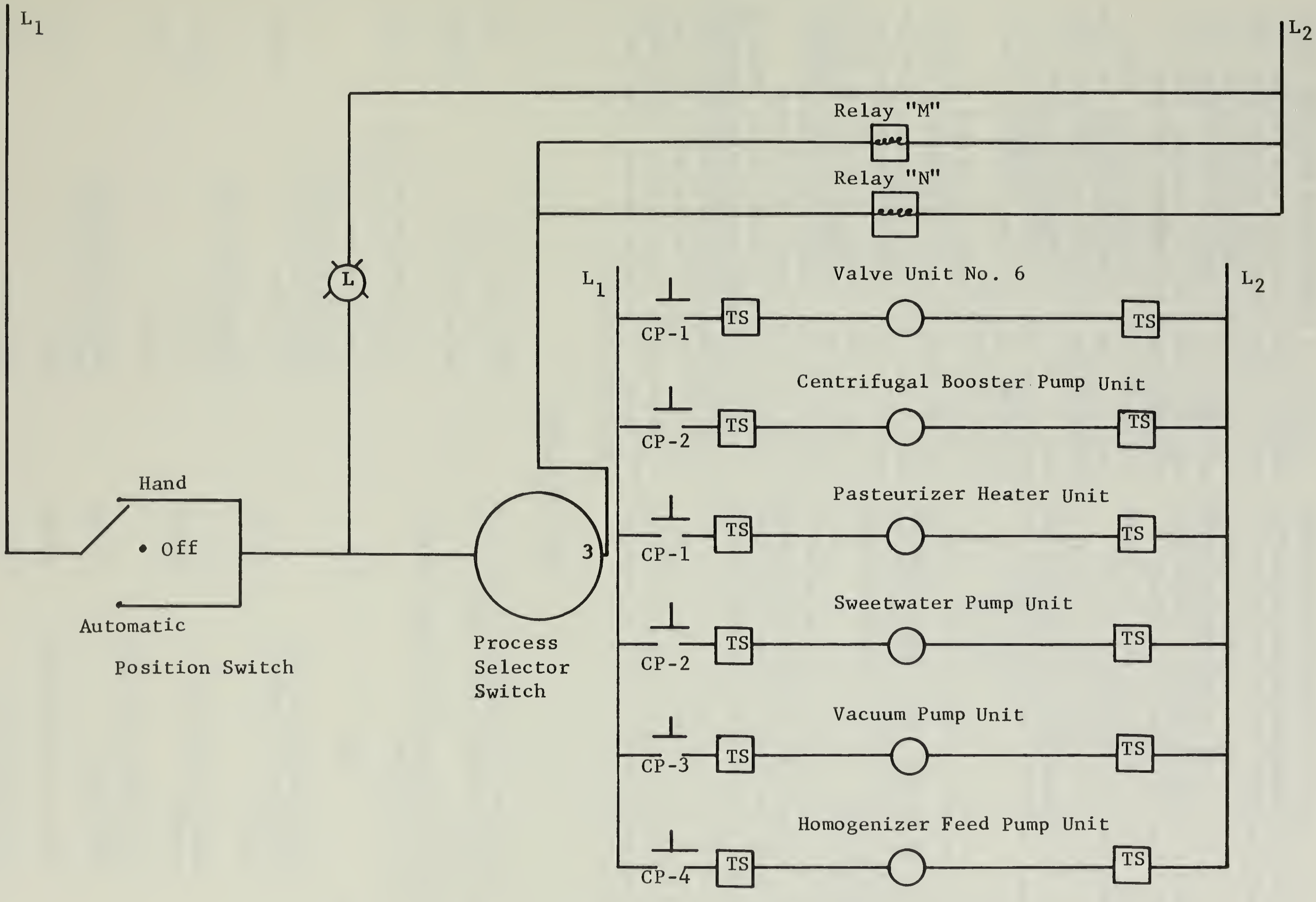


Figure 22.–Process selector switch–setting No. 3.

Setting No. 6 directs the flow of milk to tank No. 3, when it is used as a holding tank, and from tank No. 4 to the packaging equipment. This setting opens valves 8, 12, and 14, and closes valve 13, permitting the milk to flow to tank No. 3. It also opens valves 9 and 16, allowing milk to flow from tank No. 4 to the packaging equipment, and starts the agitators in tanks 3 and 4.

Valve No. 11 prevents cleaning solution from flowing to valve No. 8 during the cleaning cycle.

The transfer-to selector switch directs the flow of milk from the processing line to the pasteurized milk storage tanks, the Pure-Pak machine, the bag filler, and the can filler.

The flow-control valve (No. 7) can only be moved to the forward-flow position after the transfer-to selector switch has been energized. This prevents accidentally moving the flow-control valve to the forward-flow position before a selection on the transfer-to selector switch has been made.

Setting No. 1 (fig. 23) directs the flow of milk to tank No. 3. When relay "D" is energized, CP-1 through CP-5 are closed. The closing of CP-1 through CP-5 energizes valves 8, 13, 14, and 12, and the agitator in tank No. 3, respectively.

Setting No. 2 (fig. 24) directs the flow of milk to tank No. 4. Energizing relay "E" causes CP-1 through CP-3 to close, opening valves 9 and 15, and starting the agitator in tank No. 4.

Setting No. 3 (fig. 25) directs the flow of milk to tank No. 3, when it is used as a surge tank, and to the Pure-Pak machine, the bag filler, and the can filler. Valve units 8, 13, 14, and 12, and the agitator in tank No. 3 are energized by the closing of CP-1 through CP-5, respectively, when relay "D" is energized. Valve 10 is energized directly by the transfer-to selector switch.

Setting No. 4 (fig. 26) directs the flow of milk to tank No. 4, when it is used as a surge tank, and to the Pure-Pak machine, the bag filler, and the can filler. When relays "E" and "G" are energized, CP-1 on relay "G" energizes valve unit 16, and CP-1 through CP-3 on relay "E" energize valve units 9 and 15, and the agitator in tank No. 4, respectively.

Setting No. 5 (fig. 27) directs the flow of milk to tank No. 4, when it is used as a holding tank, and from tank No. 3 to the packaging equipment, and energizes relays "E" and "F." Relay "E" energizes valves 9 and 15, and the agitator in tank No. 4. CP-1 and CP-2 on relay "F" are closed, energizing valve No. 8 and the agitator in tank No. 3. Valve No. 10 is energized directly by deck No. 3 of the transfer-to selector switch.

Setting No. 6 (fig. 28) directs the flow of milk to tank No. 3, when used as a holding tank, and from tank No. 4 to the packaging equipment, and energizes relays "D" and "G." Relay "D" energizes valves 8, 12, 13, and 14, and the agitator in milk tank No. 3. CP-1 through CP-3 on relay "G" are closed, energizing valves 9 and 16 and the agitator in tank No. 4.

COST ANALYSIS

This analysis does not include items such as a pasteurizer, which are common to a manually operated milk processing line.

The costs of the controlling and operating units based on 1967 prices, are as follows:

Quantity	Unit	Cost
	Main control panel (one-half cost allocated to processing system)	$11,300.00
1	Liquid-level control unit (installed)	1,800.00
10	Three-position switches with indicator lights	200.00
3	Selector switches (multideck)	120.00
9	Relays, industrial type	180.00
4	Relays, plug-in type	28.00
16	Sanitary valve units	4,800.00
	Miscellaneous pipes and fittings	400.00
	Miscellaneous electrical components (wires, terminal boards, etc.) and labor for initial wiring	500.00
1	CIP flow-diversion valve, 2-inch size	1,397.25
1	Sight glass	127.65
1	Liquid level control with spray tube and throttle valve	951.05
1	Bypass valve	310.50

1	CIP booster pump (include starter)	414.00
1	Two-speed centrifugal pump (includes starters)	802.70
1	Auxiliary control panel	230.00
	Total cost of equipment	$12,560.50
	Estimated cost of installation	3,000.00
	Total cost of installed equipment	$15,560.50

Fixed Cost

Depreciation (based on average life of 12 years)[3] 0.0833 x $15,560.50	$1,296.19
Taxes and insurance (based on 4% of investment) 0.04 x $15,560.50	626.02
Interest (based on 6% of average investment $0.06 \times \left(\frac{\$15{,}560.50}{2}\right)$	469.52
Total fixed cost per year	$2,391.73
Total fixed cost per week $\frac{\$2{,}391.73 \text{ weeks}}{52 \text{ weeks}}$	$45.99

[3]Depreciation based on "Depreciation guidelines and rules," Internal Revenue Service Publication 456, 92 pp. August 1964.

The estimated yearly fixed cost of this system is $2,391.73, based on a 12-year life, or $45.99 per week. Assuming an average wage rate of $4 per hour, 11.5 man-hours per week (fig. 29) must be saved to justify the increased fixed cost of the automated system over the cost of the manually-operated system. Also, the automated system permits installation and operation of other equipment that may increase the plant's efficiency, such as a CIP cleaning system.

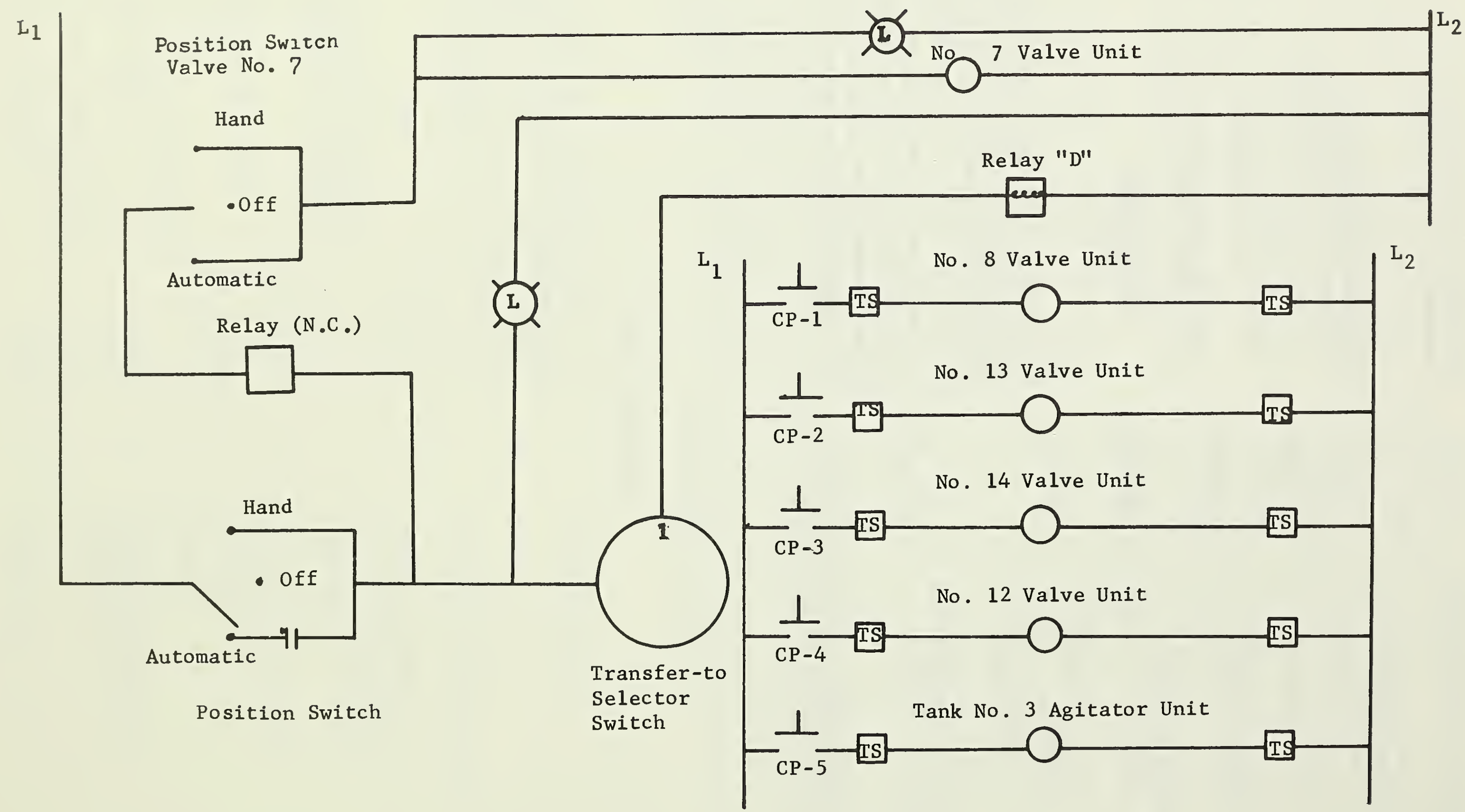


Figure 23.–Transfer-to selector switch–setting No. 1.

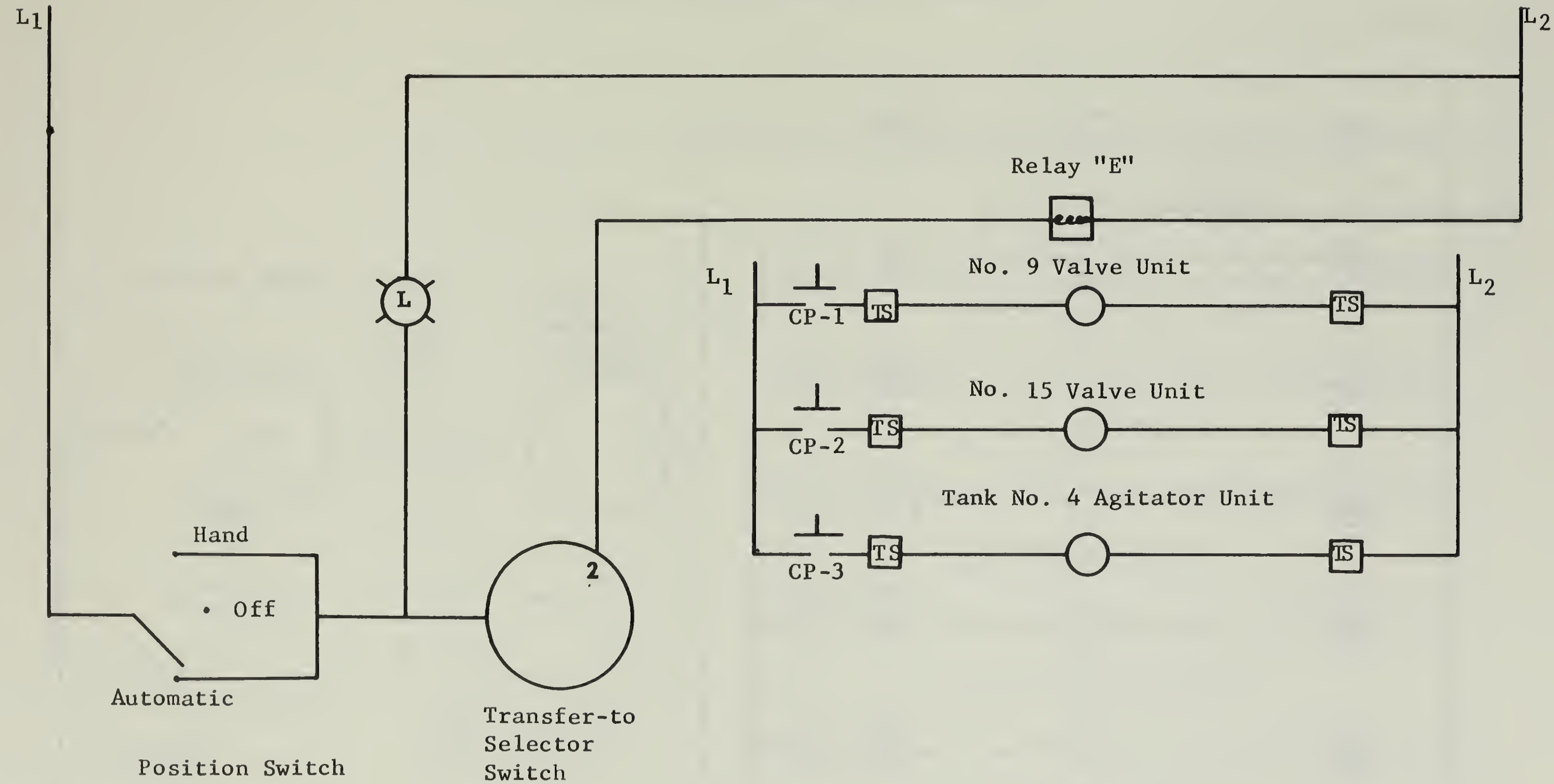


Figure 24.–Transfer-to selector switch–setting No. 2.

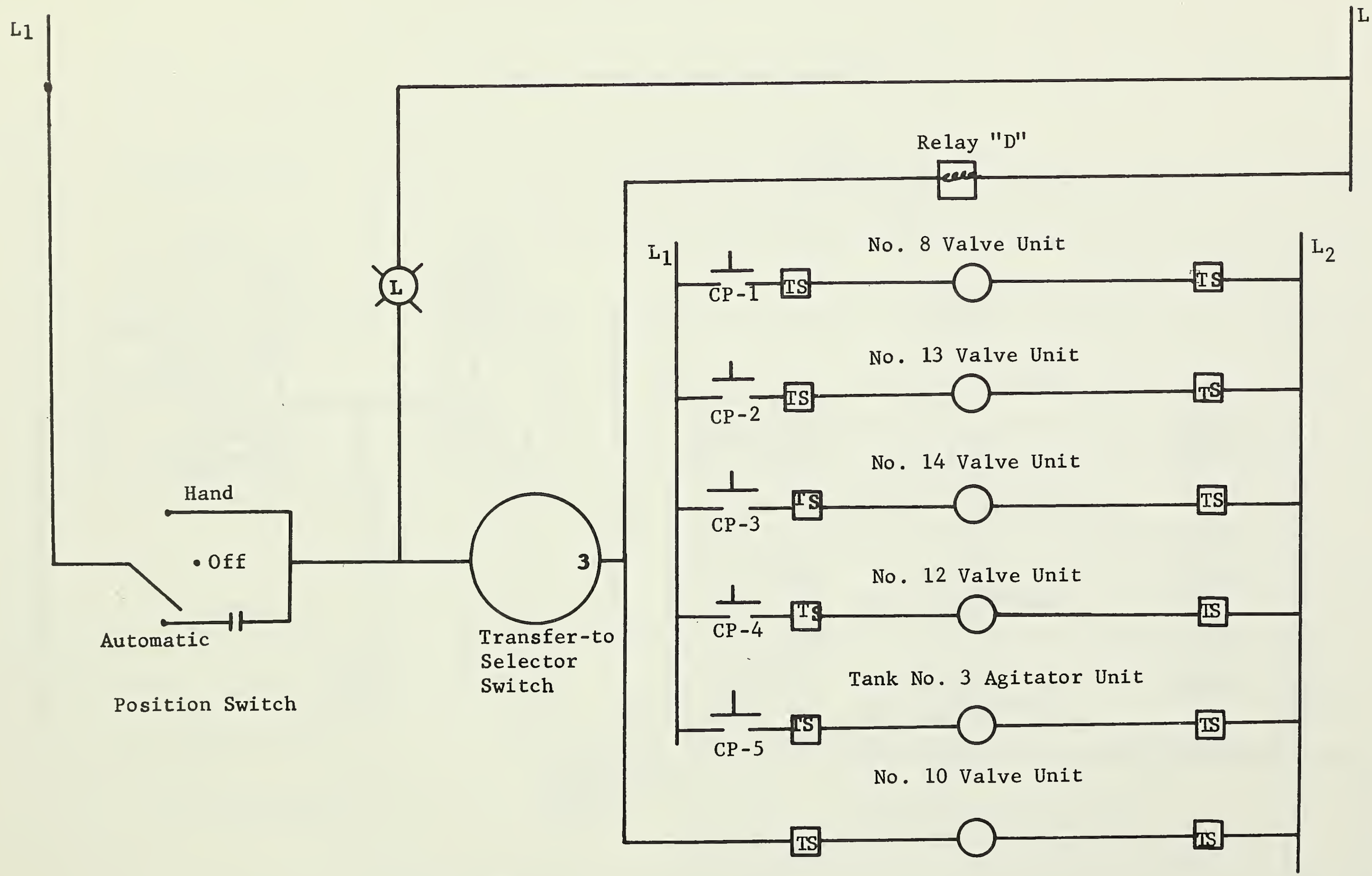


Figure 25.–Transfer-to selector switch–setting No. 3.

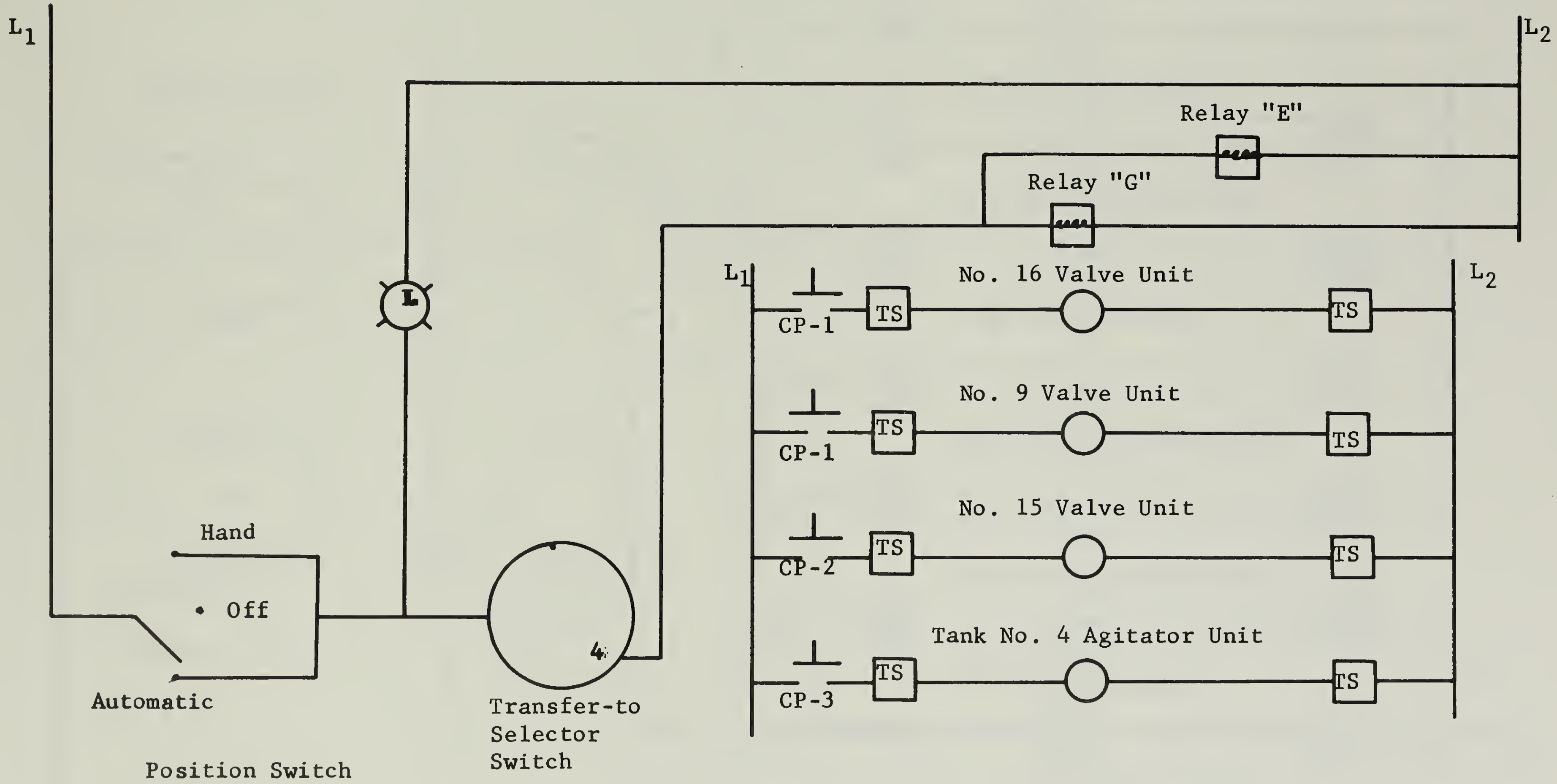


Figure 26.–Transfer-to selector switch–setting No. 4.

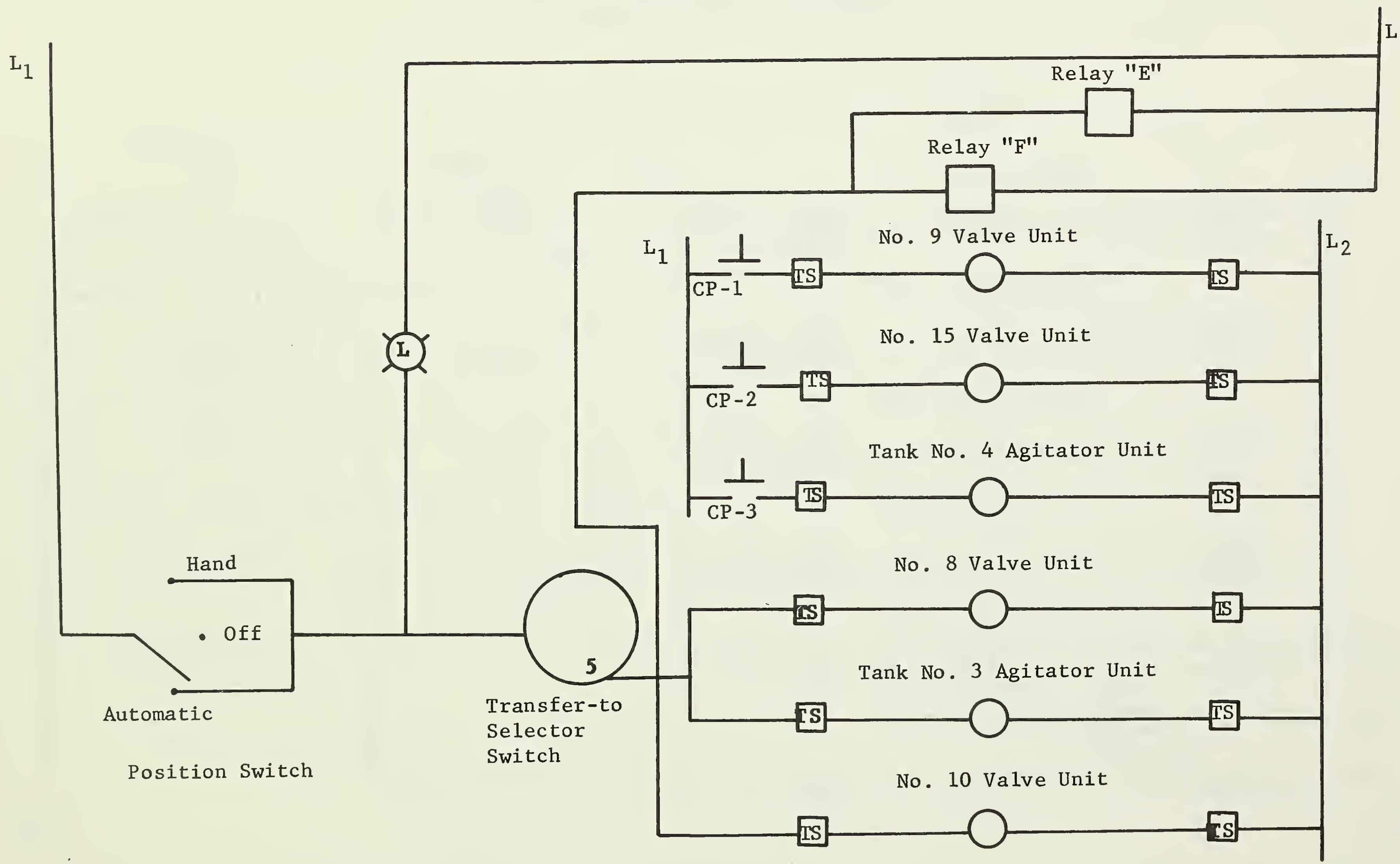


Figure 27.–Transfer-to selector switch–setting No. 5.

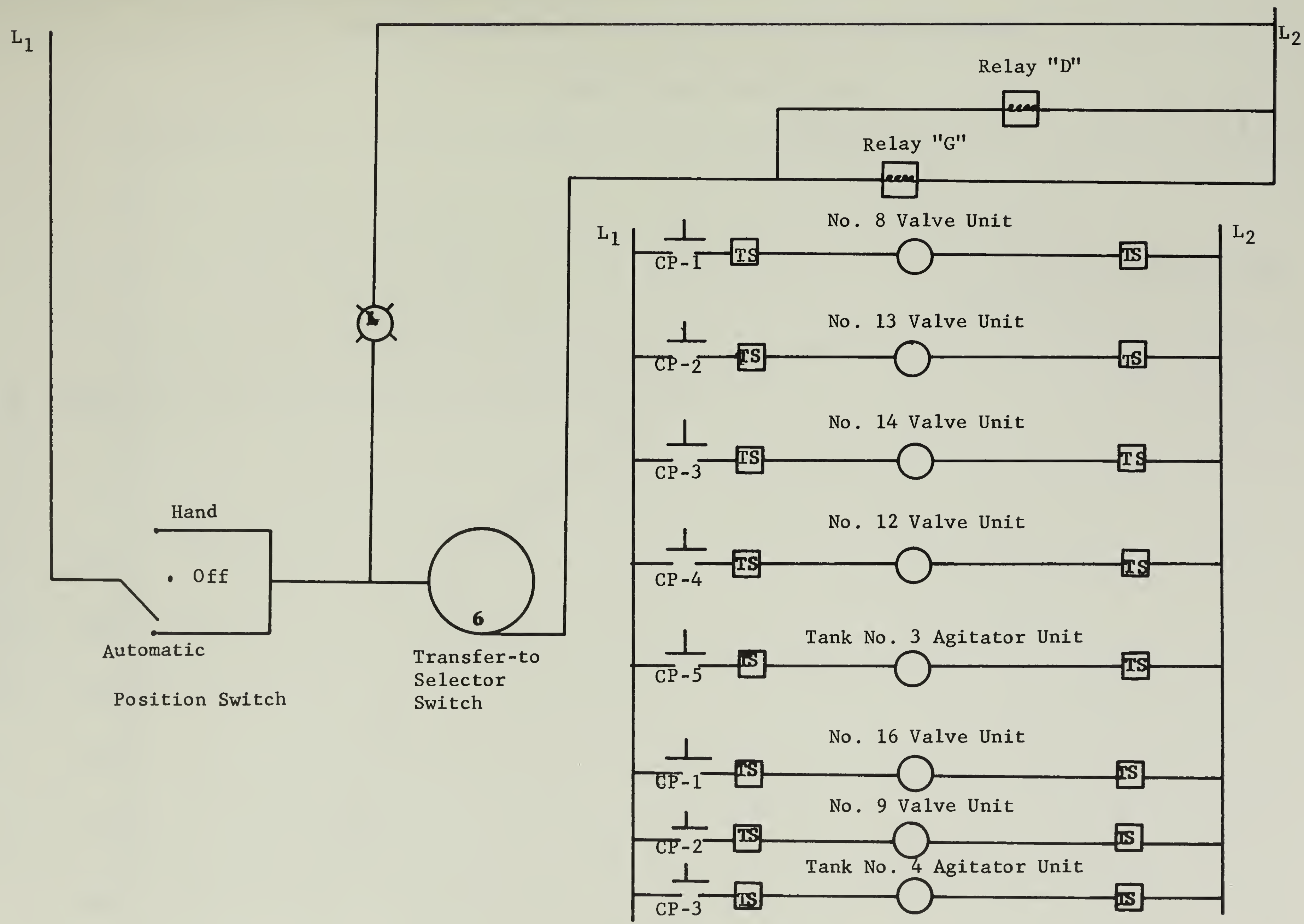


Figure 28.–Transfer-to selector switch–setting No. 6.

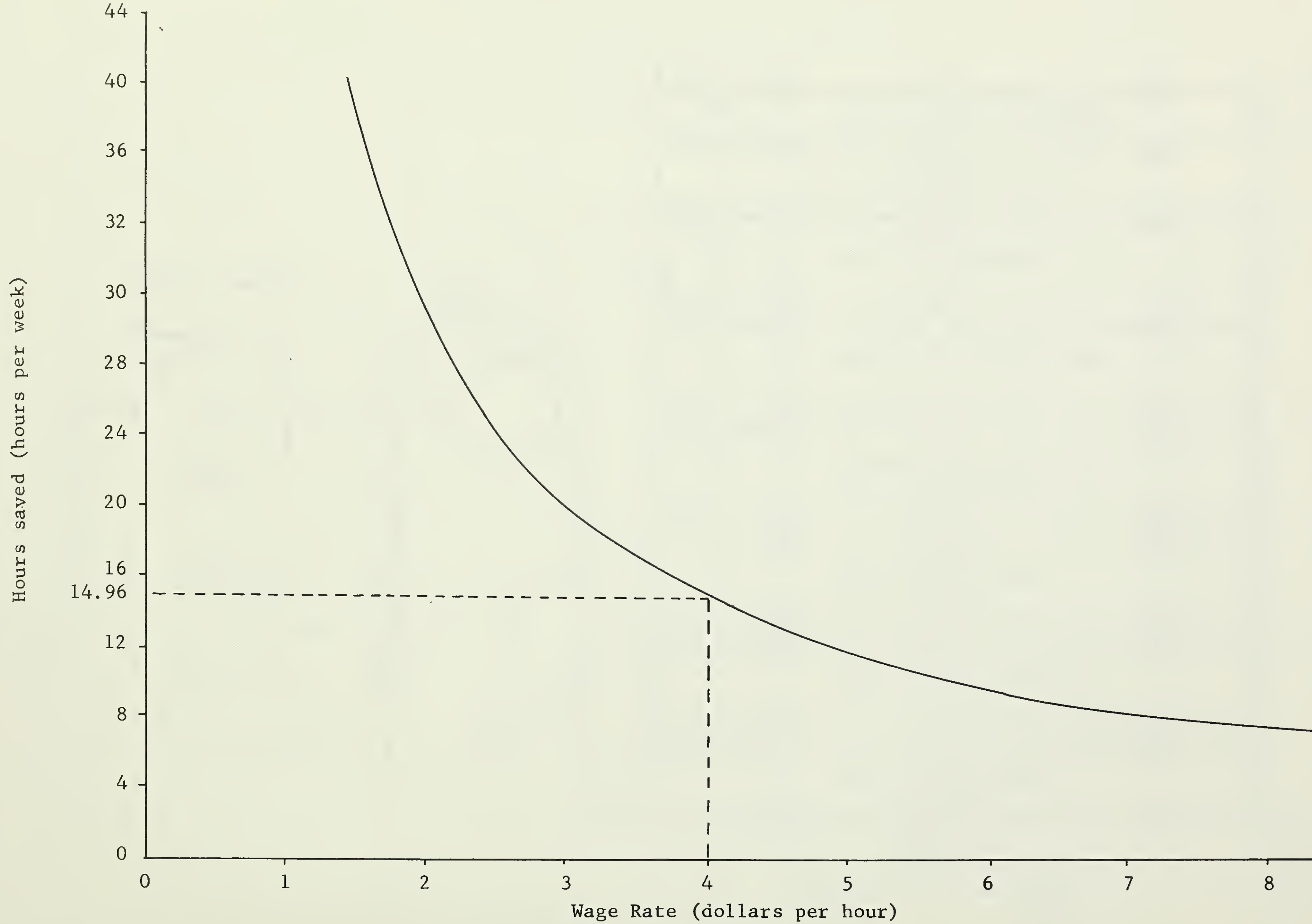


Figure 29.—Time savings required for various wage rates to justify automated processing system.

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